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Comparison of the use of Tanner and Whitehouse, NCHS, and Cambridge standards in infancy

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Abstract

The British (Tanner and Whitehouse) and American (National Center for Health Statistics, NCHS) growth standards are widely used internationally, although the data are now over 30 years old. Routine weight data was retrieved from the child health records of a complete annual cohort of 3418 children aged 18–30 months to test the validity of these standards for modern infants.

Compared with the Tanner and Whitehouse standards, Newcastle children rose initially and then fell a mean of 0·7 SDs between 6 weeks and 18 months, resulting in a threefold difference in the proportion of children below the 3rd centile at different ages. NCHS standards showed a similar pattern. When compared with modern standards from the Cambridge growth study, there was a much closer match, although Newcastle children showed a slight gain by the age of 1 year. Existing standards for weight introduce inaccuracy into the estimation of centile position in the early months of life. As both standards show similar problems this probably represents a real secular change due to changes in infant nutrition. These findings support the need to develop new national growth reference standards.

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Regular weighing is used throughout the world as a means of monitoring growth and well being in infancy, and the mainstay of weight monitoring is the growth chart. Most growth charts are produced from nationally adopted standards: in Britain those of Tanner and Whitehouse[1] and in the United States the National Center for Health Statistics (NCHS)[2] standards, both of which are also widely used internationally. Such growth standards tend to be perceived as representing an essential 'truth' about growth in a population, but this is not necessarily the case if the population from which the standards were derived is in some way different from the population to be compared with them. As both the above standards were compiled from data collected over 30 years ago, can we safely assume that they are still valid? It is known that the secular trend to increasing adult height introduces discrepancies from height standards,[3] so that, for instance, fewer children than predicted will fall below the 3rd centile. However, it is generally assumed that patterns of growth have remained constant over time. However, a study nearly 10 years ago suggested that this was not the case[4]: Whitehead and Paul demonstrated that the current pattern of weight gain in early infancy showed substantial discrepancies from the standards. These discrepancies are still not widely recognised and their clinical implications have not previously been evaluated.

We compared a large data set of weights in infancy, compiled as part of a study of the prevalence and geographical distribution of failure to thrive, to the Tanner and Whitehouse standards in a preliminary analysis. This revealed so poor a match that the use of existing standards was not practicable[5] and the data were compared instead to a more modern set of standards, derived from the Cambridge growth study,[6] a prospectively collected longitudinal data set.

The existence of this large weight data set provided the opportunity to go on to assess in detail the accuracy with which existing standards matched to actual weight gain in infancy and to determine whether the previously described discrepancy was peculiar to the Tanner and Whitehouse standards. We thus went on to explore the degree of divergence shown by all three standards – Tanner and Whitehouse, NCHS, and Cambridge – and the implications this has for both clinical and research practice.

Methods

The subjects were a complete annual cohort of children, resident in Newcastle in November 1989 and aged 18–30 months. Newcastle is an industrial city with high levels of deprivation: on a ranking using the Townsend deprivation score it is the third poorest district in the Northern region, which is itself very deprived.[7] It does not, however, have a significant ethnic minority population: 96% of the population were white at the 1991 census.[8]

The children were identified using the National Child Health Computer system. This system holds basic information, including address, postcode and general practitioner, for every child born or moving into a health district. Using this system a listing of all children in the age range was obtained and their clinic records traced. Their birth weight and up to six subsequent weights, between birth and 18 months, were then retrieved from them, as available.

Children born before 37 weeks' gestation were excluded as their growth patterns were likely to be unrepresentative, but children

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with chronic ill health were not. The medical history of children was not necessarily recorded completely in these 'well baby' records, making exclusion on health grounds unreliable. The cohort thus represented a complete population of full term Newcastle children, including those with medical disorders, simulating the actual use of growth charts in the population.

Weights were transformed into SD scores using the three different standards. For the Cambridge standards this used the LMS method.[9] For the Tanner and Whitehouse and NCHS standards the published centile data were log transformed and linearly interpolated to allow SD scores and centiles to be calculated for exact intervening ages. The data were then analysed using the Statistical Package for the Social Sciences.

Results

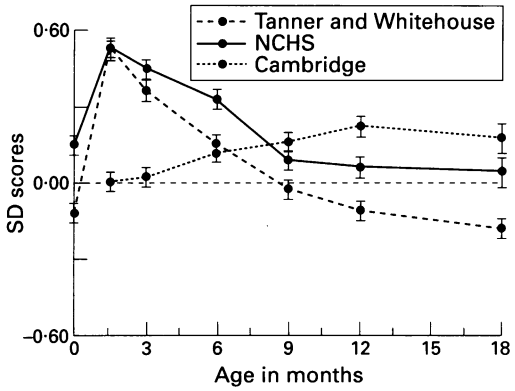
Altogether 3653 children were identified as being alive and resident in Newcastle aged 18–30 months in November 1989. Two hundred and thirty five of these children (6·4%) were recorded as having been born before 37 weeks' gestation and were excluded, leaving 3418 children. Only 47 children, 1·2% of the cohort, were identified in their records as having a chronic medical disorder that might have affected their growth. These children were not excluded for the reasons stated above.

Around 80% of the cohort had weights represented in the age bands up to 6 months, with more than 60% represented until the age of 18 months (table). A substantial proportion of missing data was due to lost records, with non-attendance affecting data availability in at most 10% of the cohort. However, as only 50% of the cohort were represented in the last age band at 18 months, it is probable that these weights were not representative of the cohort as a whole and this age band was not included in the more detailed calculations, though it is shown in the figure.

The mean weight SD scores compared with each standard were plotted against age (see figure). If there was a complete match, the median line for the cohort should be zero at all ages. It is clear that using both Tanner and Whitehouse and NCHS standards produces a major discrepancy in the early weeks. For the Tanner and Whitehouse standards this means

Per cent (number) of infants below 3rd or above 97th centile using different standards at different ages

Age	*Total No*	*Tanner and Whitehouse*	*NCHS*	*Cambridge*
Below 3rd centile				
Birth	3028	5·4 (162)	2·0 (61)	–
6 weeks	2823	1·2 (35)	0·5 (14)	3·6 (102)
3 months	2729	1·6 (43)	0·3 (9)	4·4 (120)
6 months	2668	2·2 (58)	0·9 (24)	3·6 (96)
9 months	2108	3·3 (69)	2·7 (56)	3·7 (77)
1 year	2197	3·6 (78)	2·3 (50)	3·1 (68)
Above 97th centile				
Birth	3028	2·1 (64)	1·7 (51)	–
6 weeks	2823	6·1 (172)	4·4 (124)	2·3 (65)
3 months	2729	4·6 (125)	2·3 (61)	2·3 (64)
6 months	2668	3·1 (84)	3·4 (90)	3·1 (82)
9 months	2108	2·3 (48)	3·7 (77)	4·3 (91)
1 year	2197	2·4 (52)	3·7 (81)	4·9 (107)



Mean (95% CI) weight SD scores for cohort compared with the three different standards.

that an average child apparently shifts from below zero at birth to a peak of 0·5 SD by 3 months and down again to −0·2 SD by 18 months: a shift equivalent to a fall from the 10th to the 3rd centile. For NCHS standards there is the same rise and fall, although the starting point is slightly higher, but these standards showed the closest match to the research sample from 9–18 months. The Cambridge standards showed much less discrepancy overall, although the research sample did show a gradual gain on the standards, so that they were a mean of 0·22 SD scores above the standard by the age of 1 year.

The clinical impact of these discrepancies can be demonstrated by examining their effect on the two extremes of the population: the very large and the very small. The proportion of the cohort above the 97th or below the 3rd centile at different ages as compared with each standard is shown in the table. The greatest discrepancy was between the measurements at 6 weeks and all other values. Using Tanner and Whitehouse standards there were nearly three times as many children below the 3rd centile at 12 months as there were at 6 weeks (relative risk 2·86, 95% confidence interval (CI) 1·9 to 4·3; $p<0·0001$), while for NCHS standards there were nearly five times as many (relative risk 4·59, 95% CI 2·5 to 8·3; $p<0·0001$).

For the Cambridge standards the match with the 3rd centile was very good at all ages, while there was a gradual increase in the proportion with weights above the 97th, from only 2·3% before 6 months, rising to 4·9% at a year.

Discussion

The discrepancies demonstrated between the differing standards in this study are likely to be of some relevance to practising clinicians. The period where the greatest variation is observed, between birth and 6 months, is the period over which infants show their fastest weight gain and are weighed most frequently. The potential effect of the high point at 3 months, produced by both the Tanner and Whitehouse and the NCHS standards, is that it may introduce unrealistic expectations of future growth, followed by what will then appear to be a period of growth faltering, with the possible generation of parental anxiety or even unneces-

sary investigations. Forty three infants in the cohort (over 1%), when compared with Tanner and Whitehouse standards, had crossed below the 3rd centile by the age of 1 year, having been above it at the age of 6 weeks simply as a result of this quirk in the standards. An alternative result of the observed variation may be that concerns are raised by the apparently excessive weight gain in the early months, leading to fears of obesity.

The use of either Tanner and Whitehouse or NCHS standards in research studies may also lead to a mistiming of growth faltering in vulnerable populations.[2] A study population will appear to grow relatively well in the early months and then fall away, when in reality there has been a steady falling away since birth.[10] The fact that such similar patterns are manifest in both British and American standards makes it unlikely that these are the result of some artefact in the production or the computation of the standards. Whitehead *et al* suggested in 1989 that the likeliest explanation was changing feeding practices: in the 1950s children were predominantly bottle fed, while 90% of the children in the Cambridge study were breast fed.[6] However, bottle feeding remains common in Newcastle (A Waterston, personal communication), with a pattern of early weaning similar to that prevalent in Tanner and Whitehouse's day. Nevertheless, the formulation of baby milks has changed substantially since the 1950s to resemble more closely breast milk. A study by Dewey *et al* from the USA found that both breast and bottle fed babies showed a markedly different growth pattern from the NCHS standard, very similar to that found in this study, but that the most pronounced divergence from the standards was shown by the breast fed babies.[11] While Newcastle children showed a much better match to the Cambridge standards, they did show a small, but significant, gain on the standards which was initially hard to explain. The social class distribution of Cambridge is very much more favoured than Newcastle,[8] so that it would not have excited remark had the reverse applied. However, the differing rates of breast feeding may provide an explanation for this finding, in view of the findings of Dewey *et al* in the study cited above,[11] that while the breast fed babies gained weight more rapidly in the early weeks, they had gained 0·65 kg less on average by the age of 1 year than the formula fed infants. Thus the predominantly bottle fed Newcastle infants might be expected to be heavier at 1 year of age than the breast fed infants in Cambridge.

Thus, the move towards both higher rates of breast feeding and more physiological milk formulations appears to have produced a substantial change in the normal pattern of weight gain in infancy on both sides of the Atlantic, rendering the older standards obsolete. It is expected that new British standards will soon be adopted, using a combination of pre-existing, contemporary data sets including those from the Cambridge growth study (T Cole, personal communication). It is important to remember, however, that the Tanner and Whitehouse and NCHS standards form the basis for many other national standards, particularly in developing countries where weight monitoring may have a crucial public health role. We would suggest that for international use neither weight standard is now suitable for use before the age of 1 year, and that substitute standards should now be sought.

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